INTRODUCTION

A series of multichannel seismic-reflection lines was shot over the eastern Aleutian Trench between 1977 and 1981. These lines were recorded by the R/V Lee using a GUS(R) HDDR digital seismic-recording system[1] at a 4-ms sampling interval and record lengths of as much as 12 s. The sound source, an airgun array, was energized every 50 m and detected on a hydrophone streamer having a 2,400-m active array composed of 24 hydrophone groups spaced 100 m apart, the result being 24-fold common-depth-point (CDP) coverage. The distance between the source and the nearest hydrophone group was 297 m.

These data were initially processed by the U.S. Geological Survey in Menlo Park, Calif., using their seismic-data processing system to the point of a conventional stack. The processing sequence used was CDP sort, velocity analysis, normal moveout (NMO), first-break suppression (mute), stack, predictive deconvolution, bandpass filter, water-bottom mute, and scaling.

An interpretation of these data showed that the diffractions present were obscuring most of the primary reflections. Wave-equation migration algorithms available on the seismic-data processing system (Digicon, Inc., "DISCO 80"(R) system[1]) at the U.S. Geological Survey in Denver, Colo., were applied to the stacked data to make them easier to interpret.

MIGRATION

The technique of migration can substantially improve the quality of seismic record sections by collapsing diffractions to their point of origin and imaging dipping reflectors to their true horizontal positions at depth. This is done by imaging the acoustic wave field using an approximation to the scalar wave equation (Berkhout, 1980). This method is exact when the velocity field does not vary laterally and produces a good approximation when a laterally changing velocity field is carefully studied and smoothly defined.

Many algorithms are available to perform this imaging. The one used in this study is a finite-difference technique that approximates a solution to the scalar wave equation (Claerbout, 1970; Claerbout and Doherty, 1972) and is presently in common use throughout the seismic-exploration industry.

PROCESSING TECHNIQUES

In order to determine optimum processing parameters for display, we tested stacked versions of the data that were not deconvolved, filtered, or scaled. The record sections were subsequently bandpass filtered and scaled, but were not deconvolved because the tests showed it to be unnecessary. These filtered and scaled data were then migrated. Initially, the velocity model that was used to stack the data was supplied to the migration algorithm. This produced an unacceptable result. The reason is that conventional velocity-analysis programs determine the average velocity in time to each reflecting horizon. In a deep-water environment (in our case, the water depth is greater than 4 km), the constant-velocity water layer is the most dominant term in this average. At these depths, the velocity changes between relatively thin layers (interval velocities) are difficult to resolve because the average velocities determined by the analysis programs are nearly the same. Because accurate migration depends on determination of interval velocities, we abandoned further efforts to define migration velocities on the basis of stacking velocities.

After much experimentation, we used the following testing sequence to determine migration velocities:

1. The record sections were migrated four times with constant velocities of 1,450, 1,550, 1,650, and 1,750 m/s, respectively.
2. These four migrated results were inspected in the manner of constant velocity analysis for stacking, and a new velocity model was constructed. We attempted to define variations in velocity as smoothly as possible.
3. The new velocity model was used in migrating the data. Water-bottom mute and scaling were applied immediately before display.

The above processing scheme worked well and efficiently for these data. By using constant-velocity migrations as described, an optimum velocity model for migration was determined. Migration revealed folds and faults previously obscured by diffractions. We suspected that the data could be improved further if stacking velocities could be determined more accurately. The original stacked data contained errors resulting from picking diffractions rather than reflections from stacking velocity analyses as well as those errors associated with deep water, as described above. We decided to apply migration to line 111 prior to NMO and stack, using the migration velocity model previously determined. We then performed velocity analysis on the migrated data, determined a new stacking-velocity model, and used this model to apply NMO and stack. Errors resulting from picking diffracted energy were eliminated because the energy was already collapsed to its origin by the migration process.

The quality of the resulting stacked data was significantly improved. However, the efficiency of the initial processing scheme was lost because, at equal sample rates, the time required to migrate before stacking is directly proportional to the stack fold. Line 111 is 24 fold but, fortunately, the frequency content of the data allowed us to increase the sampling interval from 4 to 8 ms, hence reducing the data by one-half. Even so, migration before stacking took 12 times longer than migration after stacking. For this reason, only the areas having complicated geologic structure and a large amount of diffracted energy were migrated before stacking. They are line 111, line 117 (CDP 50-950), line 119 (CDP 526-1175), and line 113 (CDP 400-800).

[1]Any use of trade and company names is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.

EFFECT OF MIGRATION

Figure 2 shows a portion of line 111 at various stages of processing. Figure 2*A* is a conventionally stacked, unmigrated version, which shows that diffractions obscure most primary reflections. Figure 2*B* is a version of the data from 2*A*, migrated after stacking. Migration collapsed the diffractions to their origin and revealed complicated folding and thrust faulting. Note especially that at CDP 250 at a time of 8 s, the image of the thrust-fault plane is resolved sloping upward to the right. The data in figure 2*C* were migrated before stacking, analyzed for stacking velocity to determine a new velocity model, and then stacked. The quality of the data was significantly improved over that of figure 2*B*: signal-to-noise ratio is better, positions of faults are easier to determine, reflections underneath the folding have increased continuity (CDP 360, 9 s), and deeper reflectors are present (CDP 215, 10 s). A detailed geologic interpretation of this line, including complete displays of the unmigrated time-and-depth sections and those migrated after stacking, was done by von Huene and others (1983). Complete displays of the data migrated before stacking and corresponding geologic interpretations have also been done by von Huene and others (in press); part of the interpretation in depth is shown in figure 2*D*.

FINAL MIGRATED CROSS SECTIONS

Figures 3 and 4 show migrated dip lines and strike lines, respectively, in terms of two-way travel time. A depth scale for reference is shown at the ends of each cross section. Depths were determined from velocity information from refraction experiments performed in the study area (Shor and von Huene, 1972). A time-varying function was developed for shelf, slope, and trench sections and was interpolated between lines. The velocity functions were tied at line intersections. Line-intersection points are shown on the cross sections.

CONCLUSIONS

Wave-equation migration has significantly improved the quality of seismic-reflection data in the Aleutian Trench area. The scheme of migrating with constant velocities is an effective method for constructing an optimum velocity model for migration in areas of complex structure and deep water. Migration before stacking can improve the quality of the data, but due to its time-consuming nature should be used only for detailed study in areas of high interest.

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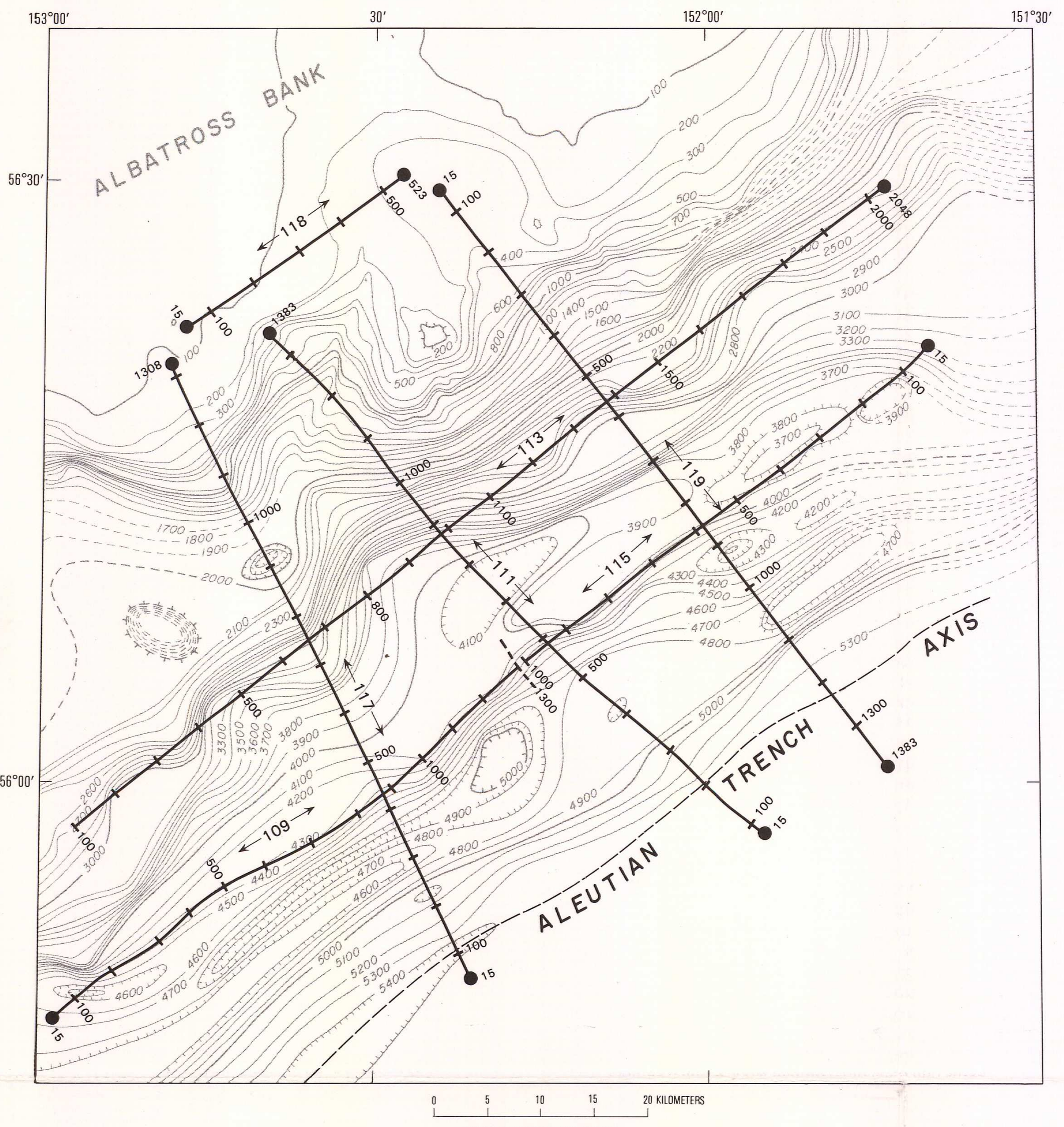
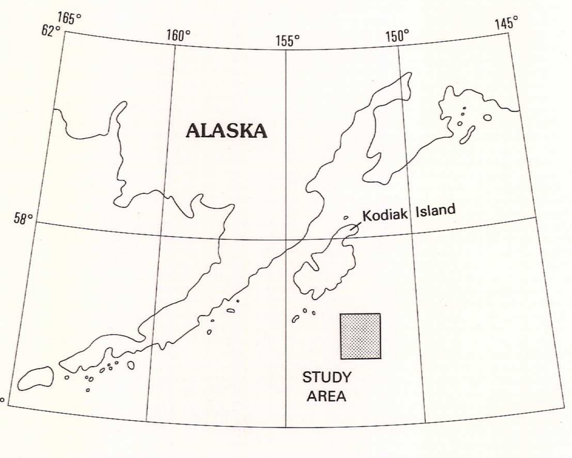


Figure 1.—Map showing location of seismic-reflection lines 109, 111, 113, 115, 117, 118, and 119

Annotation at tick marks corresponds to CDP numbers plotted at top of record section (figs. 2–4). Base map is bathymetric map of Aleutian Trench off Kodiak Island based on seismic survey lines about 12 km apart (modified from von Huene and others, 1983)



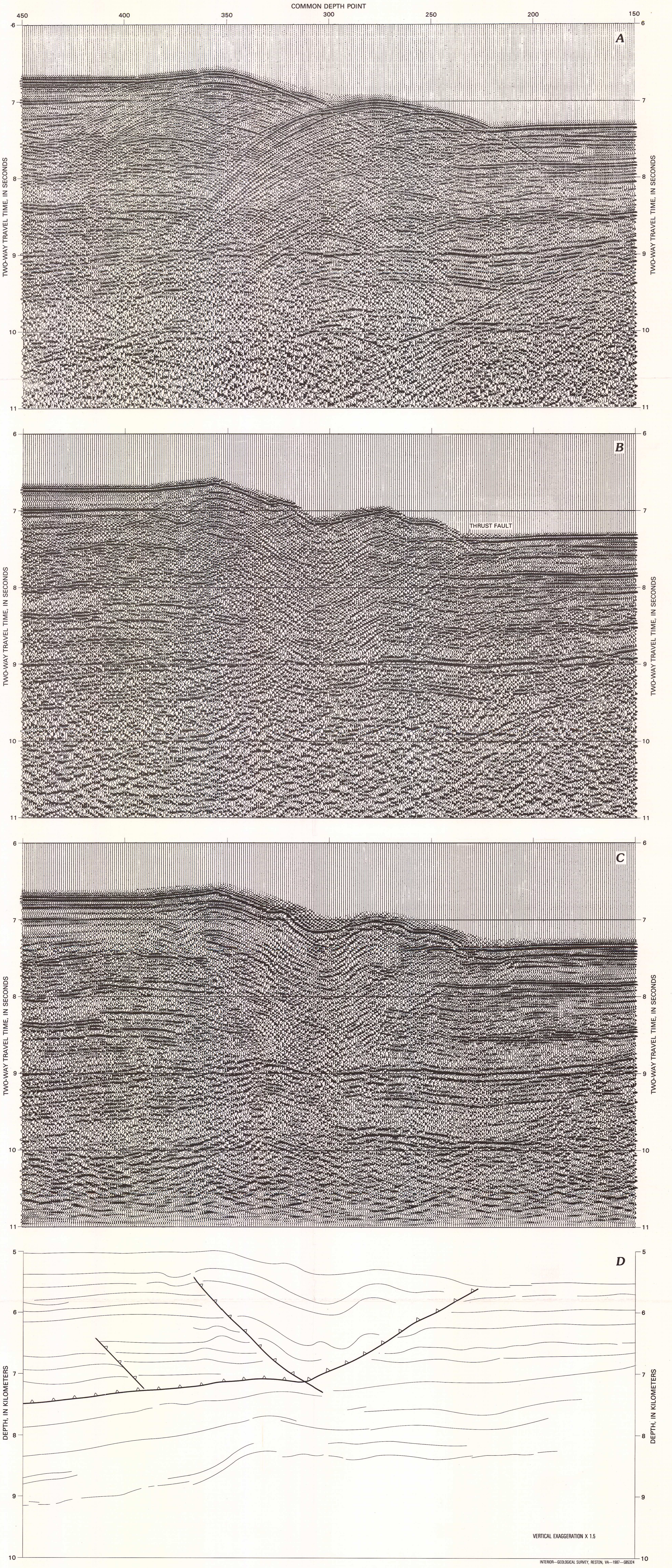


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Figure 2.—Effect of migration on part of seismic-reflection line 111

A. Unmigrated, stacked record section, in time
B. Data from *A* migrated after stacking, showing folding and thrust faulting revealed after collapse of diffractions
C. Data from line 111 migrated before stacking, showing improved quality of data, compared to *B*
D. Geologic interpretation of *C*, in depth (modified from von Huene and others, in press)

MIGRATED SEISMIC-REFLECTION LINES, EASTERN ALEUTIAN TRENCH

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